

AD-A160 175

PRODUCTION OF CN (A2PI I) IN THE PHOTOLYSIS OF
ACETONITRILE AT 158 NM(U) HOWARD UNIV WASHINGTON DC
LASER CHEMISTRY DIV J B HALPERN ET AL. 30 SEP 85

1/1

UNCLASSIFIED

ONR-TR-18 N00014-80-C-0305

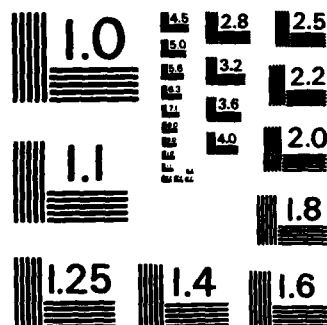
F/G 7/5

NL

END

FILED

DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS
BEFORE COMPLETING FORM

1. REPORT NUMBER ONR-TR-18	2. GOVT ACCESSION NO. AD-A160175	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Production of CN ($A^2\Pi_i$) in the Photo- lysis of Acetonitrile at 158 nm		5. TYPE OF REPORT & PERIOD COVERED TECHNICAL REPORT 18
7. AUTHOR(s) Joshua B. Halpern and Xiao Tang		6. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS Laser Chemistry Division Department of Chemistry Howard University, Washington, D.C.		8. CONTRACT OR GRANT NUMBER(s) N00014-80-C-0305
1. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research Department of the Navy Arlington, VA 22217		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBER NR-051-733
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE September 30, 1985
		13. NUMBER OF PAGES 17
		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; reproduction is permitted for any purpose of the United States Government; distribution is unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) Distribution of this document is unlimited.		
18. SUPPLEMENTARY NOTES Prepared for publication in the Journal of Chemical Physics Letters.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Originator supplied key words include: Photodissociation, BrCN, Photolysis, UV <u>Asymmetric $A^2\Pi_{sub i}$</u> <u>d sub 3</u>		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The primary product of the photolysis of acetonitrile and d_3 - acetonitrile in the first Rydberg system absorption at 158 nm is shown to be CN ($A^2\Pi_i$). Near collision free measurements of the quantum state distributions in the $A^2\Pi_i$ $v'=0$ level detect little rotational excitation in the CN fragment. The population of the $v'=1$ level of the CN ($A^2\Pi_i$) state is less than 10% of that in the $v'=0$ level. The occupation of the $\Pi_{3/2}$ and $\Pi_{1/2}$ manifolds seems to be statistical. <u>$\Pi_{sub 3/2}$</u> <u>$\Pi_{sub 1/2}$</u>		

DD FORM 1 JAN 73 1473

EDITION OF 1 NOV 43 IS OBSOLETE
S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

AD-A160 175

DTIC FILE COPY

DTIC
ELECTE
S OCT 8 1985
A

D

OFFICE OF NAVAL RESEARCH

Contract N00014-80-C-0305

Task No. NR 051-733

TECHNICAL REPORT NO. 18

PRODUCTION OF CN ($A^2\Pi_i$) in the Photolysis of Acetonitrile
at 158 nm

by

Joshua B. Halpern and Xiao Tang

Prepared for Publication in Chemical Physics Letters

Laser Chemistry Division
Department of Chemistry
Howard University
Washington, D. C. 20059

September 30, 1985

Reproduction in whole or in part is permitted for any purpose of
the United States Government

This document has been approved for public release and sale, its
distribution is unlimited

85 10 07 041

Production of CN ($A^2\Pi_1$) in the Photolysis
of Acetonitrile at 158 nm

Joshua B. Halpern and Xiao Tang*

Department of Chemistry

Howard University

Washington, DC 20059

Current address: Pohl Institute, Tong Ji University
Shanghai, People's Republic of China

ABSTRACT

The primary product of the photolysis of acetonitrile and d_3 -acetonitrile in the first Rydberg system absorption at 158 nm is shown to be CN ($A^2\Pi_1$). Near collision free measurements of the quantum state distributions in the $A^2\Pi_1$ $v'=0$ level detect little rotational excitation in the CN fragment. The population of the $v' = 1$ level of the CN ($A^2\Pi_1$) state is less than 10% of that in the $v' = 0$ level. The occupation of the $\Pi_{3/2}$ and $\Pi_{1/2}$ manifolds seems to be statistical.



TAGGED	
INTS. CH. CI	<input checked="" type="checkbox"/>
DTIC TAG	<input type="checkbox"/>
Unann. med	<input type="checkbox"/>
Justified	
By _____	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

1.0 INTRODUCTION

We have measured the quantum state distribution of CN ($A^2\Pi_i$) fragments from the photolysis of CH_3CN at 158 nm. Methyl cyanide has two weak continuous absorption systems. The first extends symmetrically from 180 to 160 nm (1), and the second goes from 160 to 130 nm with a maximum at 137 nm (2). The latter has a rapid increase in absorption at 145 nm. The first band is an intervalence $n \rightarrow \sigma^*$ transition while the second is the first Rydberg system (3). We report here on the photolysis of CH_3CN at 158 nm, at the beginning of the Rydberg system.

The CN ($A^2\Pi_i$) origin lies at 9118 cm^{-1} , and its vibrational frequency is 1933 cm^{-1} (4). The $\text{CH}_3\text{-CN}$ bond strength is $42,900\text{ cm}^{-1}$ (5). When the CN fragment is produced in the A state following photodissociation at 158 nm, there will be $11,275\text{ cm}^{-1}$ of excess energy available for partitioning into the vibrational and rotational degrees of freedom of the fragments.

The photochemistry and spectroscopy of acetonitrile were summarized by Ashfold, MacPherson and Simons (6). Simons and Ashfold have used atomic resonance lamps to excite Rydberg transitions and have studied the dispersed emission from the CN ($B^2\Sigma^+$) fragments (7). West observed CN ($A^2\Pi_i$) emission from CH_3CN and a number of other CN containing compounds illuminated with tunable synchrotron radiation (8). For acetonitrile only a threshold measurement of 172 nm was reported.

Recently Cody, Dzvonik and Glicker studied the photolysis of acetonitrile using a broadband flash lamp and LIF detection of CN

($X^2\Sigma^+$) fragments (9). The appearance of signal monitoring the ground state fragment was slow (about 10-20 ns between the photolysis and the signal maximum). When a quenching gas was added the LIF spectrum was dominated by signal from CN quenched from the $A^2\Pi_1$ to the $X^2\Sigma^+$ state (10).

The first LIF measurement of quantum state distributions from photolysis was of the CN ($X^2\Sigma^+$) fragment formed in the VUV photolysis of C_2N_2 (11). Since then this technique has been used to measure state distributions of many different photolysis products from many parent molecules (6,12,13). The photolysis of nitriles has been studied extensively because of the ease of measuring the CN ($X^2\Sigma^+$) state population by LIF, and the CN ($B^2\Sigma^+$) state distribution by emission spectroscopy.

Measurements of the CN ($A^2\Pi_1$) level by emission spectroscopy are more difficult because of the appreciably longer lifetime of this state (6 μ s vs 60 ns for the ($B^2\Sigma^+$) state) (11,14,15), and the fact that the 0,0 band of the CN ($A^2\Pi_1 \rightarrow X^2\Sigma^+$) transition lies at about 1,100 nm. Recently, we showed that populations in low vibrational levels of the CN ($A^2\Pi_1$) state could be monitored by LIF excitation of the ($A^2\Pi_1 \rightarrow B^2\Sigma^+$) system (16). Dorthé and co-workers have had good success in monitoring CN ($A^2\Pi_1$) with a special red-sensitive photomultiplier tube (17).

EXPERIMENTAL

We used a flashlamp-VUV monochromator combination of our construction as the photolysis source at 158 ± 2 nm (18).

CN ($A^2\Pi_1$) fragments were monitored by LIF excitation of the $A^2\Pi_1$ $\rightarrow B^2\Sigma^+$ (0,0), (2,0) and (3,1) bands, with a 400 kW nitrogen laser pumped dye laser which emitted between 0.5 and 1 mJ of tunable light per pulse.

The LIF signal was relatively weak, so that a 100 MHz photon counter (Photochemical Research Associates) was used to quantify the LIF signal. Signal from an EMI 9813 photomultiplier tube was sent to a fast amplifier and signal discriminator. Logic pulses from the discriminator were routed to the photon counter. The counter was modified to be gated by a timing pulse derived from the laser trigger. The gate was set to open when the laser fired, and last for 120 ns, which is about two lifetimes of the excited $B^2\Sigma^+$ state. This eliminated scattered room light and photomultiplier dark current. Scattered laser light was suppressed because the excitation was at 600 nm or 480 nm while the fluorescence occurred at 388 nm.

The photon counter accumulated counts for 200 laser pulses and then cleared itself. Simultaneously it latched the total into a D/A converter. The resulting analog signal was displayed on a strip chart recorder. The highest peaks were about 100 counts.

As it took hours to run a single spectrum, we measured the band head region at the end of each run and compared it with the measurement of this region at the start. Any degradation or drift in the apparatus would be noted in this comparison.

Spectral grade acetonitrile supplied by Fisher was degassed by freezing and thawing and used without further purification.

RESULTS

Typical results are shown in Figure 1 for excitation of the (0,0) band. Because of the relatively low intensity of the dye laser (about 1 mJ), low Einstein coefficient for the LIF transition ($5 \times 10^4 \text{ s}^{-1}$) (19,20), and low absorption of CH_3CN at 158 nm, we were not quite able to achieve collisionless conditions. The low signal-to-noise ratio is primarily due to the last factor. For example, in the same apparatus the 158 nm photolysis of 20 mtorr of cyanogen ($\sim 10^{-16} \text{ cm}^2$) the signal-to-noise ratio is well over 1000.

In view of the fact that the excess energy for photolysis of CH_3CN to produce CN ($A^2\Pi_1$) is over $11,000 \text{ cm}^{-1}$ the spectrum in Figure 1 shows little energy partitioned into rotation. Figure 2 is a Boltzmann plot of the log of the signal divided by the laser intensity and the rotational line strengths vs. rotational energy of the CN ($A^2\Pi_1$) fragments. Although there is much scatter, the data seems to be describable by a straight line fit corresponding to a temperature of $800 \pm 300 \text{ K}$.

The given conditions of pressure and delay between the photolysis and the probing laser correspond to an average of one gas kinetic collision at room temperature. Considering the amount of excess energy available from the photolysis, the fastest CN fragments would experience an average of three to four

collisions before they were excited by the dye laser. It has been commonly observed that high rotational states are not efficiently cooled by collision, and in particular for CN, Wittig's group has shown that rotational states with $N > 40$ are not cooled after several tens of collisions (21). In our experience in measuring the nascent quantum state distributions of CN fragments from photolysis, given a rotational distribution describable by a Boltzmann distribution with a temperature well above ambient, the effect of a few collisions is to transform the rotational distribution to a bimodal one. This bimodal distribution is the sum of two Boltzmann like terms, with one having a temperature near ambient and the other close to the elevated, nascent temperature. One can understand this behavior as being due to efficient cooling of the lower levels, where the separation in energy between rotational states is high, and inefficient cooling of higher lying states, where the separation between adjacent states is large.

In light of this, the absence of a bimodal nature in the distribution of Figure 2, indicates that the effect of collisional cooling is small. The absence of highly excited rotational levels is almost conclusive as to the lack of significant rotational excitation, since these states would ordinarily not be efficiently quenched. One must exercise some caution, as no rotational quenching rates for CN colliding against CH_3CN have been measured.

To measure the vibrational distribution we excited the $\Delta v = +2$ progression of the CN ($A^2\Pi_1 \rightarrow B^2\Sigma^+$) system. For the $\Delta v = 0$

progression, the Franck-Condon factor of 0.01 for the (1,1) transition is 20 times less than the Franck-Condon factor of 0.30 for the (0,0) band. In contrast, the Franck-Condon factors for the (2,0) and (3,1) bands are 0.22 and 0.31 respectively (22). Figure 3 shows the LIF spectrum of this system. The signal-to-noise is somewhat less than that in Figure 1 because of the lower intensity of the dye laser in the blue region, and higher superfluorescence. Any signal at the P_2 and Q_2 bandheads of the (3,1) system is below the noise. These bandheads are quite prominent in the (3,1) bands from other photolysis of C_2N_2 . We estimate the amount of CN ($A^2\Pi_1$ $v'=1$) to be less than 10% of $v'=0$ product.

We tried to monitor CN produced in the $X^2\Sigma^+$ state by LIF. We were not able to measure any signal immediately following photolysis, in agreement with the results of Cody, Dzvonik and Glicker (9). Relative measurements of the oscillator strengths for the CN ($A^2\Pi_1$) \rightarrow CN ($X^2\Sigma^+$) and CN ($B^2\Sigma^+$) \rightarrow CN ($X^2\Sigma^+$) transitions in the same apparatus show that we should be over twenty times more sensitive for CN ($X^2\Sigma^+$) radicals than for CN ($A^2\Pi_1$) state radicals.

We have also measured the production of CN ($A^2\Pi_1$) products in the photolysis of CD_3CN . Figure 4 shows an LIF signal following the dissociation of deuterated acetonitrile. It appears quite similar to the spectrum from CH_3CN shown in Figure 1.

DISCUSSION

These measurements are direct evidence for the production of CN in the ($A^2\Pi_1$) state. Moreover, production of CN ($X^2\Sigma^+$) is a minor channel in the second continuum absorption system of acetonitrile. Cody, et al used a broad band flashlamp which may have excited additional states of the parent molecule, leading to direct production of ground and $B^2\Sigma^+$ state photoproducts (9). Since the thermochemical limit for the production of $B^2\Sigma^+$ radicals is 145.5 nm, no excited radicals would be produced in our experiment. This may explain their somewhat higher yield of ground state radicals, although they also show that CN ($A^2\Pi_1$) radicals are the primary product.

As CN behaves as a pseudo-halogen, in analogy to the photolysis of methyl halides one expects the photolysis of acetonitrile to be direct and simple. There has been substantial work on the photochemistry of the methyl halides, especially CH_3I (6,12,13). For excitation at 248 and 266 nm most of the I atoms are produced in the excited $^2P_{1/2}$ state (23). It is interesting to note that the excess energies for $CH_3I + h\nu \rightarrow CH_3 + I^*$ at 248 and 266 nm of 12,795 and 10,065 cm^{-1} respectively, bracket that in the 158 nm photolysis, $CH_3CN + h\nu \rightarrow CH_3 + CN (A^2\Pi_1)$.

In the photolysis of methyl iodide, IR emission and TOF experiments find that only the 580 cm^{-1} CH_3 umbrella mode (ν_2) is excited. At 266 and 248 nm, 10 or more quanta of this mode can be populated, with the distribution sharply peaked at $v^* = 2$ (24).

TOF results measure translational energy distributions of the methyl radical (25,26), and obtain vibrational distributions by fitting. Although such fits are relatively insensitive to rotational distributions, Barry and Gorry state that the rotational widths must be less than the vibrational spacing of the ν_2 mode of the CH_3 fragment which is 612 cm^{-1} (26). Hermann and Leone obtain the best fit to their IR emission spectra with a 300 K rotational distribution (24). Their distributions should be rotationally relaxed to an extent, since IR emission occurs on a slower time scale than rotational relaxation. However, it is unlikely that a great deal of energy is deposited into rotation.

The TOF distributions show that the channel producing I^* has a very sharply peaked distribution in ν_2 of CH_3 , with a maximum at $v^*=2$. The channel producing ground state atoms is associated with a flat distribution of vibrational excitation in the methyl radical extending to the thermochemical limit. This picture of the distribution of excess energy in the photolysis of the methyl halides is consistent in all details with what we have measured for acetonitrile.

In summary, the primary product of photolysis of acetonitrile at 158 nm is $\text{CN} (\text{A}^2\Pi_1)$. The amount of vibrational and rotational excitation in the CN product is very small as compared to the amount of excess energy available. The distribution of angular momentum in the methyl fragment should be what it is in the CN fragment by conservation of angular momentum. This is all consistent with the dissociation being a simple and direct repulsive motion along the $\text{CH}_3\text{-CN}$ bond. As

expected the stiff CN bond is not much excited by this process, but the weaker umbrella mode of the CH_3 should be.

We can reverse the above discussion of the photodissociation of acetonitrile in terms of the photolysis of methyl halides, to draw some conclusion about the latter process. Our measurement of the rotational distribution of the CN fragment shows that there is only a small amount of excitation in the rotational distributions of the CN and CH_3 fragments from acetonitrile. Therefore we conclude that there will be little relative rotational excitation of the methyl group when any of the methyl halides are photolyzed in the far UV.

ACKNOWLEDGEMENTS

We wish to thank Dr. William M. Jackson for many useful discussions pursuant to the preparation of this manuscript. This research was supported by the Office of Naval Research. Joshua Halpern was partially supported by NSF contract CHE 82-19255 while Xiao Tang thanks the Department of Energy, grant number DE-AS05-76ER05056 for his support.

FOOTNOTES

1. G. Herzberg, and G. Scheibe, Z. Physik B7 (1930) 390.
2. J. A. Cutler, J. Chem. Phys., 16 (1948) 136.
3. R. S. Stradling and A. G. London, Farad. Trans. II, 73 (1977) 623.
4. G. Herzberg and K. Huber Molecular Spectra and Molecular Structure IV. Molecular Constants of Diatomic Molecules, Van Nostrand, Princeton, New Jersey, 1982,
5. D. D. Davis and H. Okabe, J. Chem. Phys., 49 (1968) 5526.
6. M. N. R. Ashfold, M. T. MacPherson and J. P. Simons, in Topics in Current Chemistry V 86: Spectroscopy, Springer Verlag, Berlin, 1982, p. 1.
7. M. N. R. Ashfold and J. P. Simons, Farad. Trans. II, 74 (1978) 1263.
8. G. A. West, Thesis, University of Wisconsin (1975).
9. R. J. Cody, M. J. Dzvonik and S. Glicker, J. Chem. Phys., 85 (1985) 3100.
10. W. M. Jackson and R. J. Cody, J. Chem. Phys., 61 (1974) 4183.
11. W. M. Jackson, J. Chem. Phys., 61 (1974) 4177.
12. W. M. Jackson and H. Okabe, to appear in Advances in Photochemistry, Volman, Gollnick and Hammond Eds.
13. H. Okabe, Photochemistry of Small Molecules, Wiley, New York, 1978.
14. W. A. Payne, J. B. Halpern and W. M. Jackson, Proceedings of the International Conference on Lasers: 1982, SPIE, p 72.

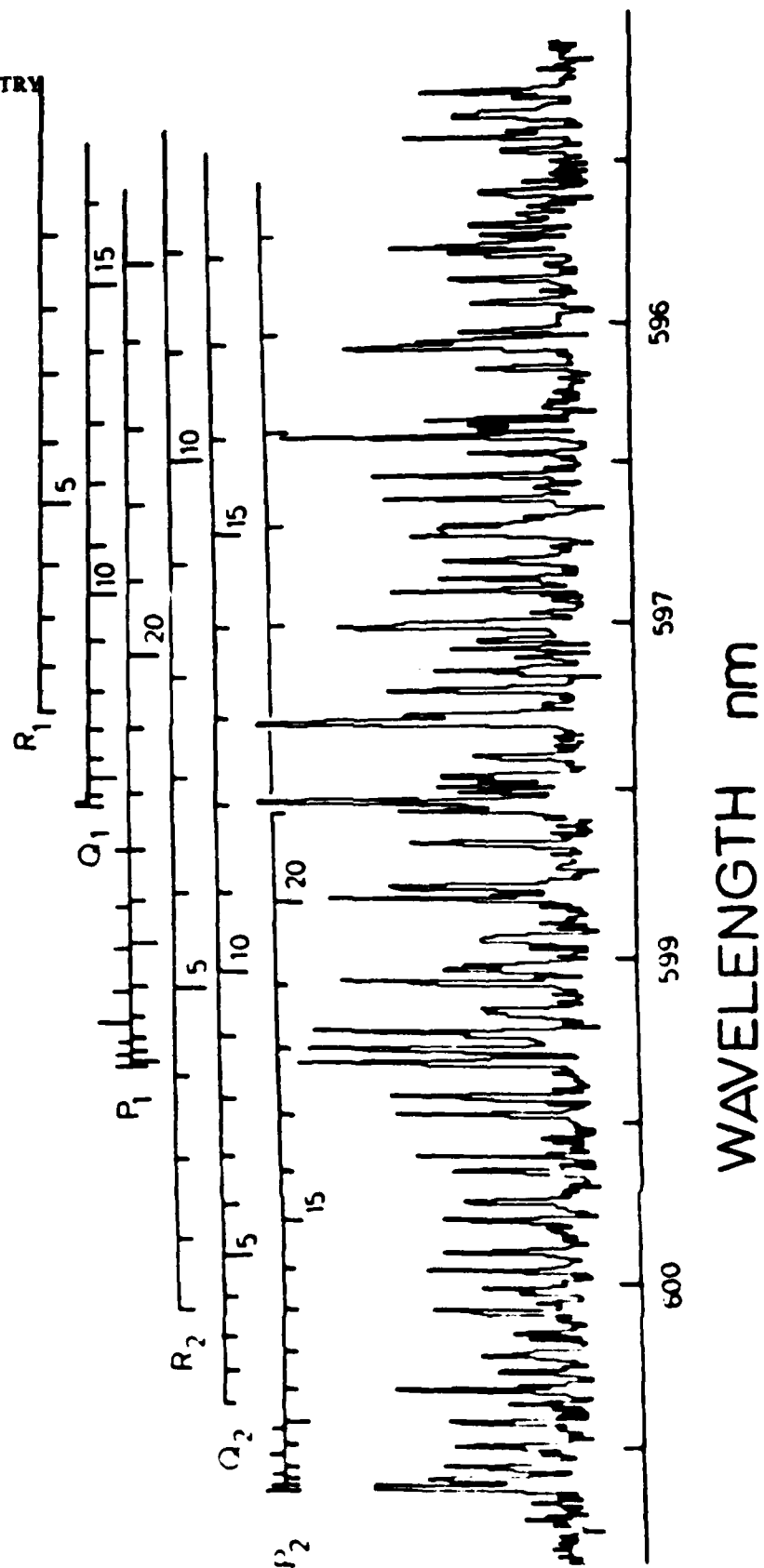
15. M. R. Taherian and T. G. Slanger, J. Chem. Phys., 81 (1984) 3814.
16. C. Conley, et al., Chem. Phys. Lett., 73 (1980) 224.
17. M. Costes, G. Dorthe and M. Destriau, Chem. Phys. Lett., 61 (1979) 588.
18. G. E. Miller, W. M. Jackson and J. B. Halpern, J. Chem. Phys., 71 (1979) 4625.
19. J. B. Halpern and X. Tang, Chem. Phys. Lett., 97 (1983) 170.
20. M. Costes, C. Naulin and G. Dorthe, J. Chem. Phys., 82 (1985) 2313.
- 21.
22. L. Schoonveld, J. Quant. Spec. Rad. Trans., 12 (1972) 1139.
23. H. W. Hermann and S. R. Leone, J. Chem. Phys., 76 (1982) 4766.
24. W. H. Pence, S. L. Baughcum and S. R. Leone, J. Phys. Chem., 85 (1981) 3844.
25. G. N. A. van Veen, T. Baller and A. E. DeVries, Chem. Phys., 87 (1984) 405.
26. M. D. Barry and P. A. Gorry, Molec. Phys., 52 (1984) 461.

FIGURE CAPTIONS

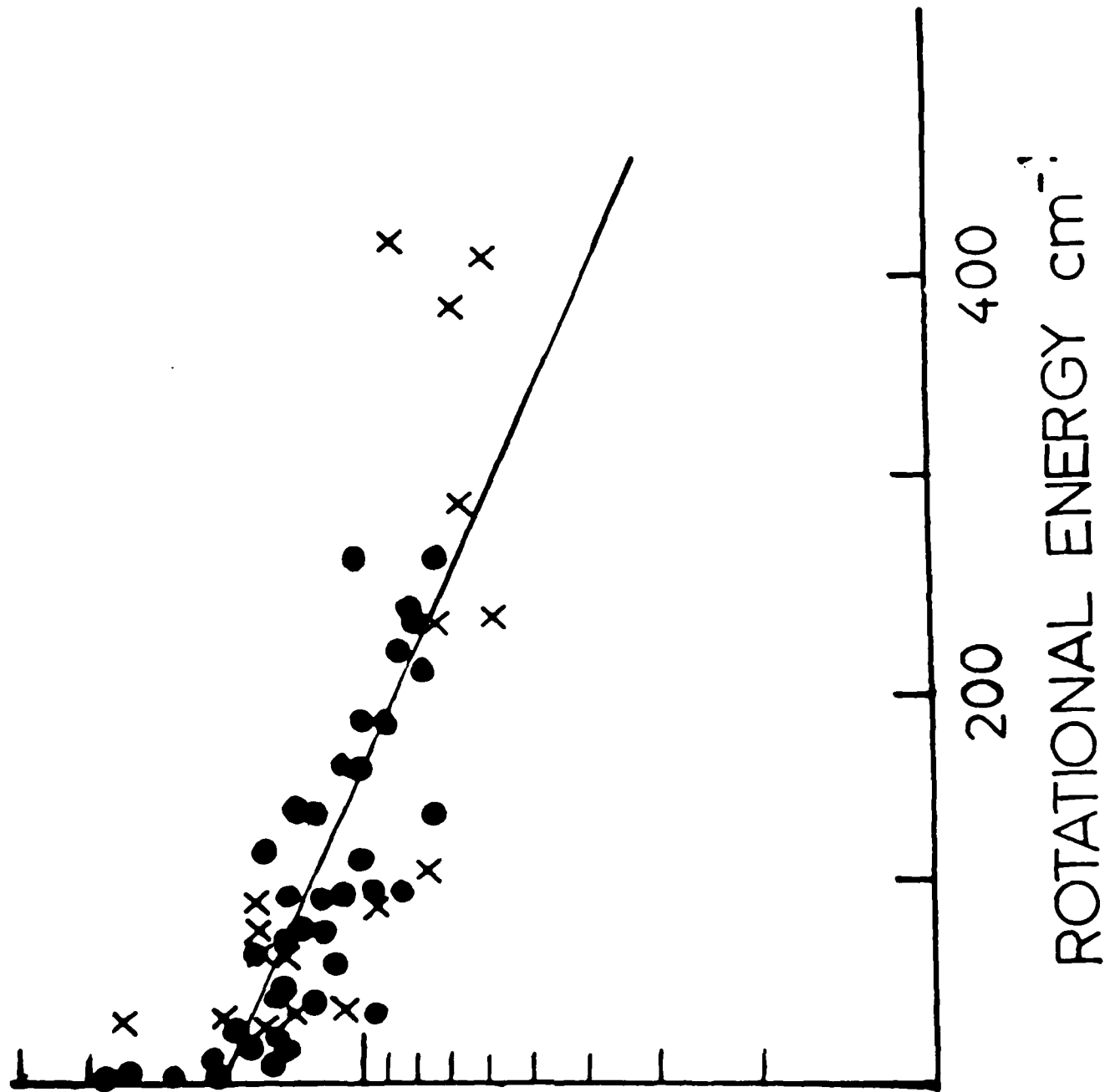
- Figure 1. LIF spectrum of CN ($A^2\Pi_1$) fragments from the photolysis of CH_3CN at 158 nm. The spectrum is of the (0,0) band of the CN ($A^2\Pi_1 \rightarrow B^2\Sigma^+$) system. The pressure of CH_3CN was 100 mtorr and the delay between photolysis and probing 1 μsec .
- Figure 2. Quantum state distribution of rotational energy in the $v' = 0$ level of CN ($A^2\Pi_1$) state fragments produced in the photolysis of CH_3CN at 158 nm. The closed circles represent states in the $\Pi_{3/2}$ manifold and the crosses levels in the $\Pi_{1/2}$ manifold.
- Figure 3. LIF spectrum of CN ($A^2\Pi_1$) fragments from the photolysis of CH_3CN at 158 nm. The spectrum is of the (2,0) band of the CN ($A^2\Pi_1 \rightarrow B^2\Sigma^+$) system. The pressure of CH_3CN was 500 mtorr and the delay between photolysis and probing 1 μsec . Note the absence of signal in the (3,1) band.
- Figure 4. LIF spectrum of CN ($A^2\Pi_1$) fragments from the photolysis of CD_3CN at 158 nm. The spectrum is of the (0,0) band of the CN ($A^2\Pi_1 \rightarrow B^2\Sigma^+$) system. The pressure of CD_3CN was 85 mtorr and the delay between photolysis and probing 1 μsec .

HOWARD UNIVERSITY
WASHINGTON, D.C. 20059

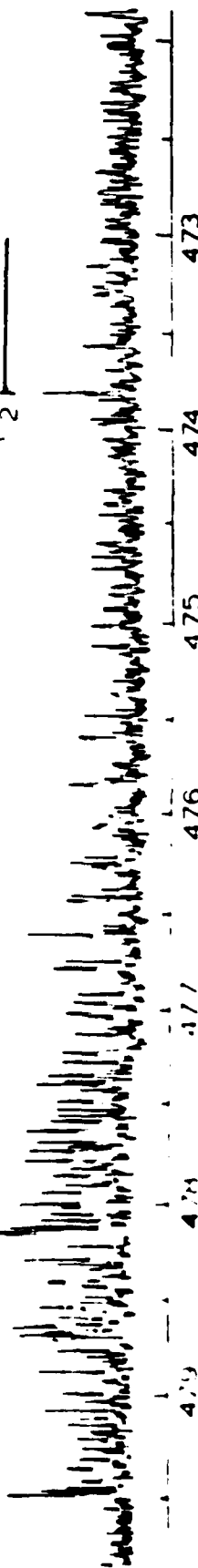
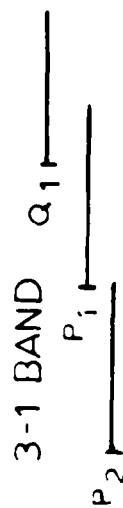
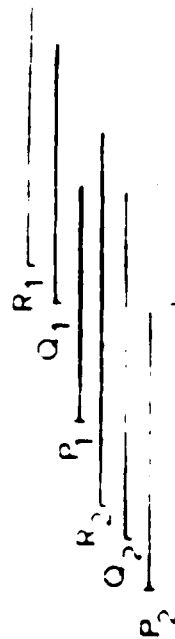
DEPARTMENT OF CHEMISTRY



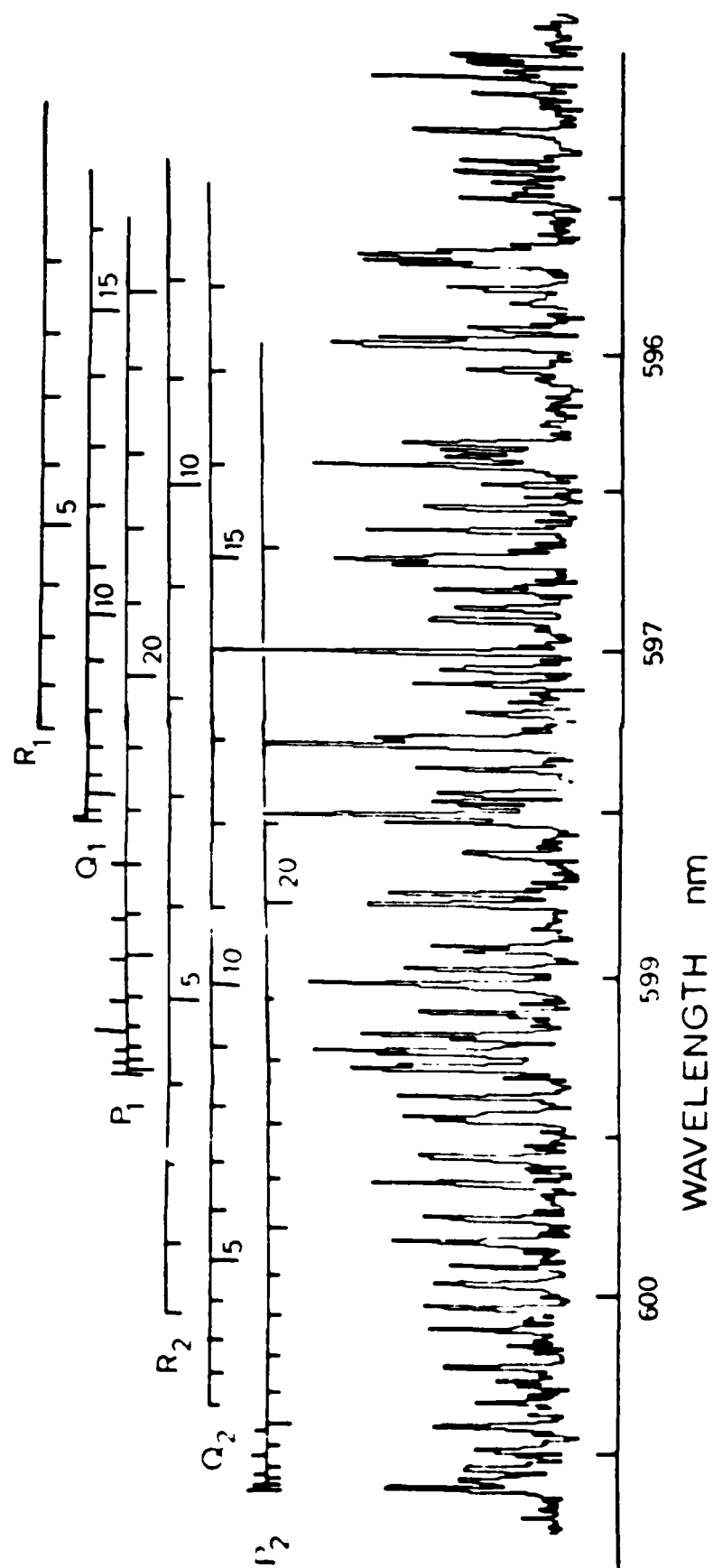
$\log (\text{SIGNAL} / S_{j'j''} I_{\text{LASER}})$



2-0 BAND



WAVELENGTH (μ)



TECHNICAL REPORT DISTRIBUTION LIST, GEN

	<u>No. Copies</u>		<u>No. Copies</u>
Office of Naval Research Attn: Code 413 800 N. Quincy Street Arlington, Virginia 22217	2	Dr. David Young Code 334 NORDA NSTL, Mississippi 39529	1
Dr. Bernard Douda Naval Weapons Support Center Code 5042 Crane, Indiana 47522	1	Naval Weapons Center Attn: Dr. Ron Atkins Chemistry Division China Lake, California 93555	1
Commander, Naval Air Systems Command Attn: Code 310C (H. Rosenwasser) Washington, D.C. 20360	1	Scientific Advisor Commandant of the Marine Corps Code RD-1 Washington, D.C. 20380	1
Naval Civil Engineering Laboratory Attn: Dr. R. W. Drisko Port Hueneme, California 93401	1	U.S. Army Research Office Attn: CRD-AA-IP P.O. Box 12211 Research Triangle Park, NC 27709	1
Defense Technical Information Center Building 5, Cameron Station Alexandria, Virginia 22314	12	Mr. John Boyle Materials Branch Naval Ship Engineering Center Philadelphia, Pennsylvania 19110	1
DTNSRDC Attn: Dr. G. Bosmajian Applied Chemistry Division Annapolis, Maryland 21401	1	Naval Ocean Systems Center Attn: Dr. S. Yamamoto Marine Sciences Division San Diego, California 92161	1
Dr. William Tolles Superintendent Chemistry Division, Code 5100 Naval Research Laboratory Washington, D.C. 20375	1		

TECHNICAL REPORT DISTRIBUTION LIST, 051A

Dr. M. A. El-Sayed
Department of Chemistry
University of California
Los Angeles, California 90024

Dr. E. R. Bernstein
Department of Chemistry
Colorado State University
Fort Collins, Colorado 80521

Dr. J. R. MacDonald
Chemistry Division
Naval Research Laboratory
Code 6110
Washington, D.C. 20375

Dr. G. B. Schuster
Chemistry Department
University of Illinois
Urbana, Illinois 61801

Dr. J.B. Halpern
Department of Chemistry
Howard University
Washington, D.C. 20059

Dr. M. S. Wrighton
Department of Chemistry
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

Dr. A. Paul Schaap
Department of Chemistry
Wayne State University
Detroit, Michigan 48207

Dr. W.E. Moerner
I.B.M. Corporation
5600 Cottle Road
San Jose, California 95193

Dr. A.B.P. Lever
Department of Chemistry
York University
Downsview, Ontario
CANADA M3J1P3

Dr. John Cooper
Code 6173
Naval Research Laboratory
Washington, D.C. 20375

Dr. George E. Walrafen
Department of Chemistry
Howard University
Washington, D.C. 20059

Dr. Joe Brandelik
AFWAL/AADO-1
Wright Patterson AFB
Fairborn, Ohio 45433

Dr. Carmen Ortiz
Consejo Superior de
Investigaciones Cientificas
Serrano 121
Madrid 6, SPAIN

Dr. John C. Wright
Physics Department
University of New Hampshire
Durham, New Hampshire 03824

Dr. Kent R. Wilson
Chemistry Department
University of California
La Jolla, California 92093

Dr. G. A. Crosby
Chemistry Department
Washington State University
Pullman, Washington 99164

Dr. Theodore Pavlopoulos
VOSC
Code 531
San Diego, California 91232

END

FILMED

11-85

DTIC